compressed. Ames Research Center (ARC) is developing solid-state adsorption compression and separation technology to acquire the Mars atmospheric constituents and make them available for downstream processing or direct use.

The ARC adsorption compression technology uses a zeolite adsorbent bed that can adsorb large quantities of carbon dioxide at the ambient temperature and pressure of the Mars surface. Its capacity for the other Mars gases is much lower; these gases are drawn through the adsorbent and stored in a second bed for later processing. When the adsorbent is saturated with carbon dioxide, the compressor is isolated and warmed. Carbon dioxide then evolves from the sorbent, resulting in a rapid pressure increase inside the compressor. When the pressure reaches a desired level, the carbon dioxide can be drawn off. The supplied pressure is easily regulated by controlling the power level of the compressor heater. When the supply of carbon dioxide is exhausted, the bed is allowed to cool and to adsorb another load of carbon dioxide. The cycle can be repeated indefinitely.

The first uses for this adsorption compression technology will be on robotic exploration missions. A prototype for adsorption compression at this mission scale is shown in the figure. The one-kilogram device shown has been tested successfully under simulated Mars surface conditions, under which it produces approximately 15 grams of carbon dioxide per day at a pressure of 120 kiloPascals (17.4 pounds per square inch), and requires an average of 7 watts of power during 5 hours of production. Larger-scale productions will be more economical as the fraction of structural mass decreases, with an anticipated daily production level of about 250 grams carbon dioxide per kilogram of compressor mass.

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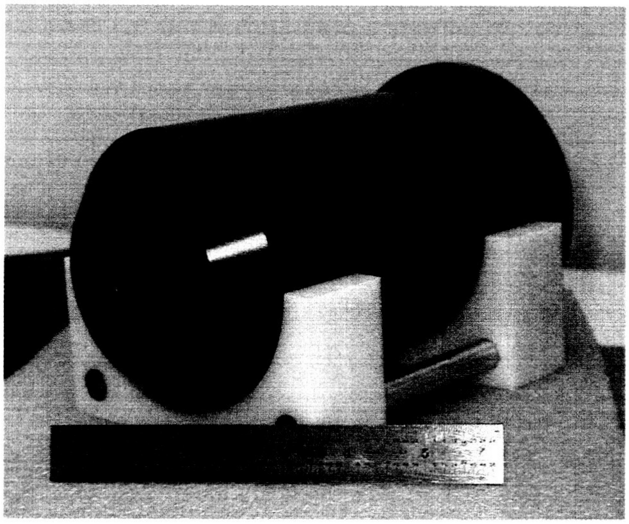

Fig. 1. Prototype solid-state adsorption compressor for Mars carbon dioxide, 15 grams/day scale. A nitrogen/argon mixture is produced as a byproduct.

Dynamic Modeling of Life Support Systems

Cory Finn and Harry Jones

Dynamic system models have been developed that track the flow of material through a regenerative life support system over time periods of months to years. These models are being used to help evaluate system design and operation issues for the Advanced Life Support Systems Integrated Test Bed (ALSSITB). The model captures the main flow stream characteristics associated with atmosphere regeneration, water recovery, crop growth, food processing, and waste processing. The system simulation quantifies the variations in stream flow rates and subsystem processing rates so that estimates can be made on buffer requirements for various system configurations and design options. It is also being used to investigate scheduling, operations, and control issues.

Dynamic modeling is an important tool for developing robust system designs. Static or steady-state models are often used to obtain estimates on nominal processor flow rates and resupply requirements. However, more detailed system design requires information on processor operation ranges and system buffer requirements that are a function of the system dynamics and control strategy. In general, the level of model complexity needed increases throughout the system design cycle. In the early design phase, simple dynamic models provide useful information for estimating the processing rates and storage sizes needed to meet all the system performance specifications. More complex models are needed for the design of control systems, the development of failure recovery approaches, and the plan for adding redundancy to the system in order to improve system safety and reliability.

A top-level dynamic system model of the ALSSITB has been developed at Ames Research Center (ARC) to investigate system design issues. The ALSSITB is currently being developed by Johnson Space Center (JSC) to support long-duration human testing of integrated life support systems. It comprises a set of interconnected test chambers with a sealed internal environment capable of supporting a four-person test crew for periods exceeding one year. The life support systems to be tested will consist of both biological and physical/chemical technologies that perform air revitalization, water recovery, biomass production, food processing, and solid waste processing. A variety of system designs for the ALSSITB have been studied to date.

Each system design is described in terms of the set of technologies used, the configuration of the technologies in the system, and the manner in which the system is operated. The overall technology set available for consideration includes technologies that provide various levels of regeneration. For example, life support consumables can be either supplied or produced, and waste products can be either processed, dumped, or stored. An optimal system generally consists of some combination of resupply, in situ resource utilization, venting, dumping, and material recycling using physical/chemical or biological processors. System configuration refers to the manner in which the processors are connected for a given set of technologies. For example, multiple flow paths are possible, as well as various options for the placement and sizing of buffers. System operation strategies need to be investigated because some system components can be operated in numerous ways. Some technologies can be operated in either batch mode or continuous mode. For batch operation, the batch sizes and operation schedule can vary. For continuous operation, processing rates can be either constant or variable, and the operational parameters, control objectives, and constraints can vary.

Among the ALSSITB designs simulated thus far are systems with different air revitalization systems using various circulation patterns, technology sets, and operational strategies. For each system design that was simulated, the results were compared with those of a baseline to see how well each system met performance criteria by maintaining controlled atmospheres, adequate reserves, etc., and to determine the required capacity for the various processors and storages.

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Activated Carbon from Inedible Biomass

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As manned missions become longer, resupply of life support materials becomes increasingly more difficult and expensive. The expense of resupply can be avoided by regenerating life support materials. Bioregeneration involves the use of plants to grow food, but plants generate a large amount of inedible biomass, which must be recycled. Incineration is one of the most promising technologies for recycling wastes such as inedible biomass. Unfortunately, inherent to the process of incineration is the formation of undesirable byproducts such as nitrogen oxides (NO_x) and sulfur oxides (SO_x). Conventional incineration technologies treat offgases, such as NO_x and SO_x, by using selective catalytic reduction processes, but these technologies require the injection of expendables such as ammonia to treat the NO_x. Activated carbon can also be used to remove NO_x and SO_x via the process of adsorption.

The Solid Waste Resource Recovery project group is investigating unique ways to use crop wastes to make activated carbon. This process would